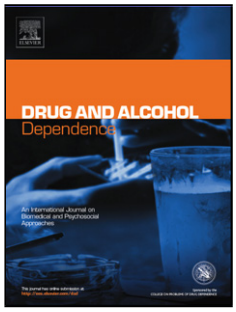
Accepted Manuscript



Title: Sleep and use of alcohol and drug in adolescence. A large population-based study of Norwegian adolescents aged 16 to 19 years

Author: Børge Sivertsen Jens Christoffer Skogen Reidar Jakobsen Mari Hysing

PII: S0376-8716(15)00082-4
DOI: http://dx.doi.org/doi:10.1016/j.drugalcdep.2015.01.045
Reference: DAD 5466

To appear in: *Drug and Alcohol Dependence*

Received date: 5-12-2014
Revised date: 25-1-2015
Accepted date: 30-1-2015

Please cite this article as: Sivertsen, B., Skogen, J.C., Jakobsen, R., Hysing, M.,Sleep and use of alcohol and drug in adolescence. A large population-based study of Norwegian adolescents aged 16 to 19 years., *Drug and Alcohol Dependence* (2015), http://dx.doi.org/10.1016/j.drugalcdep.2015.01.045

HIGHLIGHTS

- We examined the association between sleep and alcohol and drug use among adolescents
- Data stem from a large population-based sample
- We used detailed measures of sleep problems, and alcohol and illicit drug use
- All sleep parameters were associated with substance involvement
- All associations were in a dose-response manner

Sleep and use of alcohol and drug in adolescence.
A large population-based study of Norwegian adolescents aged 16 to 19 years.

Børge Sivertsen [1,2,3], Jens Christoffer Skogen [1,4], Reidar Jakobsen [5], Mari Hysing [5]

1) Norwegian Institute of Public Health, Division of Mental Health, Kalfarveien 31, 5018 Bergen, Norway

2) Department of Psychiatry, Helse Fonna HF, P.O.Box 2170, N-5504 Haugesund, Norway

3) Uni Research Health, Bergen, P.O.Box 7810, N-5020 Bergen, Norway

4) Alcohol and Drug Research Western Norway, Stavanger University Hospital, P.O.Box 8100, 4068 Stavanger

5) Regional Centre for Child and Youth Mental Health and Child Welfare, Uni Research Health, P.O.Box 7810, N-5020 Bergen, Norway

Running Title: Sleep and alcohol use in adolescence

Corresponding author: Professor Børge Sivertsen, Division of Mental Health, Norwegian Institute of Public Health, Bergen, Norway, Kalfarveien 31, 5018 Bergen, Norway, Tel.: +47 53 20 41 01, E-mail: borge.sivertsen@fhi.no

ABSTRACT

Background: Changes in sleep patterns and increased substance involvement are common in adolescence, but our knowledge of the nature of their association remains limited. The aim of this study was to examine the association between several sleep problems and sleep behaviours, and use and misuse of alcohol and illicit drugs using data from a large population-based sample. *Methods:* A large population-based study from Norway conducted in 2012, the youth@hordaland study, surveyed 9328 adolescents aged 16-19 years (54% girls). Self-reported sleep measures provided information on sleep duration, sleep deficit, weekday bedtime and bedtime difference and insomnia. The main dependent variables were frequency and amount of alcohol consumption and illicit drug use, in addition to the presence of alcohol and drug problems as measured by CRAFFT. *Results:* The results showed that all sleep parameters were associated with substance involvement in a dose-response manner. Short sleep duration, sleep deficit, large bedtime differences and insomnia were all significantly associated with higher odds of all alcohol and drug use/misuse measures. The associations were only partly attenuated by sociodemographics factors and co-existing symptoms of depression and ADHD. *Conclusions:* To the best of our knowledge, this is the first population-based study to examine the association between sleep, and alcohol and drug use, by employing detailed measures of sleep behaviour and problems, as well as validated measures on consumption of alcohol and illicit drug use. The findings call for increased awareness of the link between sleep problems and alcohol and drugs use/misuse as a major public health issue.

KEYWORDS: Sleep; alcohol and drug use; adolescence; epidemiology; mental health.

1. INTRODUCTION

Adolescence is a transitional period characterized by both changes in sleep patterns and increased substance involvement (Carskadon, 2011; Hasler et al., 2014b; Pedersen and Skrondal, 1998; Skogen et al., 2014). A recent population-based study from 2012 showed that adolescents aged 16-19 receive less than 6.5 hours of sleep per night, and nearly one in five adolescents fulfill the DSM-5 diagnostic criteria for insomnia disorder (Hysing et al., 2013). Adolescent sleep problems have been linked to both higher rates of depressive symptoms (Sivertsen et al., 2014), poor academic performance (Dewald et al., 2010), as well as increased risk for school non-attendance (Hysing et al., 2014). Similarly, alcohol and illicit drug use among adolescents have been linked to a range of deleterious consequences, including higher risk of frequent intoxication, abuse and dependence, in addition to violence, injuries (Jacobs et al., 2001), and several adverse health outcomes (Ellickson et al., 2003; Roebuck et al., 2004; Skogen et al., 2014; Townsend et al., 2007).

The relationship between sleep problems and alcohol use has been thoroughly demonstrated in adult samples (Roehrs and Roth, 2001). A recent review in adolescents showed that several aspects of sleep problems and sleep behaviours were significantly associated with increased alcohol use (Hasler et al., 2014b). However, the majority of the included studies were conducted on small or clinical samples (Clark et al., 2001; Hasler et al., 2014a; Kenney et al., 2012, 2013), and only a few population-based studies have examined the link between sleep and use of alcohol and illicit drugs in adolescence. One exception is a large Hong Kong study of 33000+ adolescents aged 11-18 that demonstrated that weekly alcohol use assessed with a single item was associated with increased rate of insomnia symptoms (difficulties initiating/maintaining sleep, and early morning awakenings; Huang et al., 2013). However, the list of adjustment variables in that study was limited. Further, in a US study of 13000+ adolescents aged 12-17, the item "trouble sleeping during the past 6 months" was significantly associated with several variables assessing use of alcohol and illicit drugs, even after adjusting for comorbid mental health

problems (Johnson and Breslau, 2001). Similarly, a study of 12000+ US high school students found that short sleep duration (<8 hrs, assessed with a single item), was associated with increased use of marijuana and alcohol, after adjusting for demographical factors (McKnight-Eily et al., 2011). To the best of our knowledge, no large-scale studies have examined this association by employing detailed measures of both sleep behaviour and problems, as well as validated measures on alcohol and drug problems, and consumption of alcohol and illicit drug use.

Thus, the main objective of the current study was to examine the association between a range sleep problems and sleep behaviors, and use and misuse of alcohol and illicit drugs using data from a large population-based sample. We expected short sleep duration and insomnia to be related to both alcohol consumption and problematic alcohol and drug use. We also wanted to investigate if the associations could be explained by potential co-occurring mental health problems , such as symptoms of depressive symptoms and attention-deficit/hyperactivity disorder (ADHD), both of which have been linked to sleep problems and alcohol use (Owens et al., 2013; Sivertsen et al., 2014; Skogen et al., 2014).

2. MATERIAL AND METHODS

In this population-based study, we used data from the youth@hordaland survey of adolescents in the county of Hordaland in Western Norway. The youth@hordaland survey is the fourth wave of the Bergen Child study, where children born 1993-1995 are followed from elementary to upper secondary school age. All adolescents and students attending secondary education during spring 2012 were invited to participate. The main aim of the survey was to assess the prevalence of mental health problems and service use in adolescents. Data were collected during spring 2012. Adolescents in upper secondary education received information via their official school e-mail address, and one classroom school hour was allocated for them to complete the questionnaire.

2.1. Sample

Of the 19,430 invited to take part, 10,200 agreed, yielding a participation rate of 53%. All sleep variables were manually checked for validity and data from subjects providing obvious invalid responses

were omitted for further analyses. Invalid responses included 1) sleep onset latency (SOL) + wake after sleep onset (WASO) > time in bed (TIB), and 2) negative values of sleep duration and sleep efficiency. This resulted in data from 374 subjects being omitted.

2.2. Instruments

2.2.1. Sleep variables. The adolescents' typical self-reported bedtime and rise time were indicated in hours and minutes and were reported separately for weekdays and weekends. Bedtime difference was defined at the difference in hours and minutes in bedtime between weekdays and weekends. Typical time in bed (TIB) was calculated by subtracting bedtime from rise time. Sleep onset latency (SOL) and wake after sleep onset (WASO) were indicated in hours and minutes, and sleep duration was defined as TIB minus (SOL + WASO). Subjective sleep need (each individual's own perceived sleep need) was reported in hours and minutes and the phrasing of the question was "How much sleep do you need to feel rested?" Sleep deficit was calculated separately for weekends and weekdays, subtracting total sleep duration from subjective sleep need. For the purpose of the present study, sleep duration was split into 6 categories (< 5 hours, 5 to < 6 hours, 6 to < 7 hours, 7 to < 8 hours, 8 to < 9 hours, ≥ 9 hours). Only weekday data for sleep duration and sleep deficit are presented in the current paper.

Insomnia was operationalized according to the DSM-5 criteria for insomnia (American Psychiatric Association, 2013). Difficulties initiating and maintaining sleep (DIMS) were rated on a three point Likert-scale with response options "not true", "somewhat true" and "certainly true". Given a positive response ("somewhat true" or "certainly true"), the participants were then asked how many days per week they experienced problems either initiating or maintaining sleep. The participants also provided information on the duration of DIMS. A joint question on tiredness/sleepiness was rated on a three point Likert-scale with response options "not true", "somewhat true" and "certainly true". If confirmed ("somewhat true" or "certainly true") participants reported the number of days per week they experienced sleepiness and tiredness, respectively. To fulfil the DSM-5 criteria for insomnia, the adolescents had to report DIMS for at least three times a week, with a duration of three months or more, as well as tiredness or sleepiness on at least three days per week.

2.2.2. Alcohol problems and illicit drug use. Frequency and amount of alcohol consumption and illicit drug use were included as main outcome. We included a binary measure of alcohol lifetime prevalence "Have you ever tried alcohol?" (Yes/No), and illicit drug-use: "Have you ever tried hashish, marihuana or other narcotic substances?" (Yes/No). Alcohol use was measured using the self-reported units of beer, cider, wine, spirits and illegally distilled spirits usually consumed during the past 14 days. Based on this information about consumption and alcohol debut, a summed variable on gender-specific distributions was constructed: 'Never tried', 'Non-consumption' (if reported consumption was '0'), '0.1–19.9th', '20.0–79.9th', '80.0–89.9th', '90.0–100th'. Excessive alcohol consumption was defined as above the 90th centile sum (Skogen et al., 2009, 2011). Frequent intoxication was defined as drinking so much that one was clearly intoxicated more than 10 times, based on the question: "Have you ever consumed so much alcohol that you were clearly intoxicated (drunk)?", with five categories ranging from 'No, never' to 'Yes, more than 10 times'. In addition, potential alcohol and drug problems were identified using the CRAFFT. The CRAFFT-questionnaire is a screening tool developed specifically to identify problematic alcohol and drug use among adolescents (Knight et al., 1999). The questionnaire consists of 6 questions with the response categories "yes" or "no". Each question contributes to the acronym CRAFFT:

1. Have you ever ridden in a ***c***ar driven by someone (including yourself) who was "high" or had been using alcohol or drugs?
2. Do you ever use alcohol or drugs to ***r***elax, feel better about yourself, or fit in?
3. Do you ever use alcohol or drugs while you are by yourself, ***a***lone?
4. Do you ever ***f***orget things you did while using alcohol or drugs?
5. Does your family or ***f***riends ever tell you that you should cut down on your drinking or drug use?
6. Have you ever gotten into ***t***rouble while you were using alcohol or drugs?

CRAFFT have been shown to have acceptable sensitivity and specificity at a cut-off of ≥2 in international studies (Knight et al., 2003; Skogen et al., 2013). For the purposes of our study we employed this cut-off to delineate between those with drug and/or alcohol problems and those without.

2.2.3. Symptoms of depression. Depression was assessed using the short version of the Mood and Feelings Questionnaire (SMFQ; Thapar and McGuffin, 1998). The SMFQ comprises 13 items assessing depressive symptoms rated on a 3-point Likert scale. A recent study from the youth@hordaland survey yielded good psychometric properties of the official Norwegian translation and supported the uni-dimensional structure as described in the original version (Lundervold et al., 2013). The Cronbach's alpha of the SFMQ in the current study was 0.91.

2.2.4. Symptoms of ADHD. Symptoms of inattention and hyperactivity were measured using sub-scales from the official Norwegian translation of the Adult ADHD Self-report Scale (ASRS; Kessler et al., 2007). The questionnaire was originally constructed for use in adults, but has recently been validated in adolescents (Adler et al., 2012). ASRS is an 18 item self-report scale, comprising 9 items on a hyperactivity-impulsivity subscale and 9 items on an inattention-subscale. A previous validation study has found an inconsistency-adjusted sensitivity of 1.0, a specificity of 0.71, a positive predictive value of 0.52, and a negative predictive value of 1.0 (Hines et al., 2012). The Cronbach's alpha of the ASRS in the current study was 0.89.

2.3. Statistics

IBM SPSS Statistics 22 for Mac (SPSS Inc., Chicago, Ill) was used for all analyses. Logistic regression analyses were used to examine the associations between sleep variables (independent variables) and alcohol/drug use (dependent variable). Age- and gender adjusted odds-ratios (OR) are presented, as well as after additional adjustment for parental education, and symptoms of depression (SMFQ total score) and ADHD (ASRS subscales inattention and hyperactivity/impulsivity). All tests were two-tailed with the significance level set at $p < 0.05$.

2.4. Ethics

The study was approved by the Regional Committee for Medical and Health Research Ethics (REC) in Western Norway. In accordance with the regulations from the REC and Norwegian health authorities, adolescents aged 16 years and older can make decisions regarding their own health (including participation in health studies), and thus gave consent themselves to participate in the current study. Parents/guardians have the right to be informed, and in the current study, all parents/guardians received written information about the study in advance.

3. RESULTS

3.1 Demographical characteristics

In all, 9,328 adolescents provided valid responses on the relevant sleep and alcohol/drug items in the sample. The mean age was 17.9 years (SD=0.8), and the sample included more girls (53.3%) than boys (46.7%). Detailed sample information on sociodemographics factors, and sleep and alcohol/drug variables is presented in Table 1.

3.2 Sleep and alcohol use/misuse

Sleep was significantly associated with use/misuse of alcohol across all measures. As detailed in Table 2, short sleep duration was associated with having ever tried alcohol in a dose-response manner. For example, sleeping less than 5 hours/night was associated with 3-fold increased odds of having tried alcohol compared to sleeping 8 to 9 hours/night. Similar graded patterns were observed when using substantial alcohol consumption and frequent intoxication (> 10 times) as the outcome variable. Both sleep deficit (difference between sleep duration and individually perceived sleep need) and large bedtime differences between weekdays and weekends were associated with the alcohol use/misuse. The largest effects were observed between bedtime differences of >4 hours and alcohol consumption beyond 90th percentile (age- and gender-adjusted odds-ratio [OR] = 4.2). Adolescents fulfilling the DSM-5 diagnostic criteria for insomnia also had increased odds of higher alcohol use/misuse, but the associations were generally smaller in magnitude (ORs from 1.3 to 1.8). As shown in Table 2, the associations were only

slightly attenuated after adjusting for parental education and symptoms of depression and ADHD, in addition to age and gender.

3.3 Sleep and alcohol and illicit drug problems

There was a strong relationship between all sleep parameters and having ever tried an illicit drug. As showed detailed in Table 3, there was a J-shaped association between sleep duration and use of illicit drugs, with both short and long sleep duration increasing the odds of having tried drugs. As with alcohol use/misuse, there was a dose-response association between hours of sleep deficit and bedtime differences, and odds of having tried illicit drugs. All associations remained significant after full adjustment for demographics and symptoms of depression and ADHD (see Table 3 for details).

As depicted in Figure 1, sleep duration was associated with problematic alcohol and drug use (CRAFFT total score) in a dose-response manner, both in boys and girls. Adolescents classified as being CRAFFT-positive (having a problematic alcohol and drug use [CRAFFT total score ≥2]) was also associated with all sleep parameters in a dose-response manner (see Table 3 for details).

4. DISCUSSION

To sum up the main findings from this large population-based sample of adolescents aged 16-19 years: Short sleep duration, sleep deficit, large bedtime differences and insomnia were significantly associated with higher odds of all measures of alcohol and drug use/misuse. The associations were in a dose-response manner. The associations were only partly attenuated by co-existing symptoms of depression, ADHD, and sociodemographics factors.

The general pattern of associations between sleep and alcohol and drug use corresponds well with both the documented association in adults studies (Roehrs and Roth, 2001), and the results from adolescent studies (Hasler et al., 2014b). However, most previous studies have focused on limited aspects of sleep or alcohol or drug use, and typically relied on single item assessments.

In the current study, we found that the pattern of drinking behavior was closely related to several sleep patterns and sleep problems. The current study demonstrated a graded relationship between all four

sleep variables and the odds of frequent intoxication. This extends on the findings from a small-scale study of 261 college students, where Kennedy et al. (2012) found that sleep quality assessed with the Pittsburg Sleep Quality Index was strongly associated with more binge-drinking as well as greater alcohol consequences. In the current study the strongest effects were found for weekend-weekdays differences in bedtime (> 4 hours) and frequent intoxication (OR=3.0). This corresponds well with a general pattern of increased risk taking behavior in adolescents with a delayed weekend bedtime or "social jet lag", which may be defined as a quantification of the discrepancy between the circadian and social clock (Roenneberg et al., 2007). For example, O'Brien and Mindell (2005) found changes in weekday and weekends sleep patterns to significantly predict several risk-taking behaviors, including alcohol and drug use, in 388 adolescents, and Pasch et al. (2010) also found that later weekend bedtime was associated with increased substance use among 242 16-year-old adolescents. Our findings also correspond with a large study of 12 154 US adolescent students, showing an association between alcohol and drug use and short sleep duration (McKnight-Eily et al., 2011). We found similar ORs for sleep duration of 7-8 hours and having ever tried alcohol (adj OR =1.3) and illicit drugs (adj OR =1.8) as the study by McKnight-Eily et al. (2011). However, we further assessed a dose-response nature of this relationship, and the odds of sleep duration of <5 hours on alcohol and illicit drugs use were adj. OR=2.3 and adj. OR=3.8, respectively.

In addition to sleep being related to patterns of alcohol and drug use, there were consistent associations between sleep and problematic alcohol and drug use. Some of this relationship was accounted for by co-occurring ADHD and depressive symptoms, and for insomnia and problematic alcohol and drug use the association was reduced by 65% (from OR=2.3 to 1.3).

4.1 Potential mechanisms

There are several mechanisms that may explain the link between sleep and use of alcohol and drugs. First, both sleep and alcohol use in adolescence are closely linked to increased mental health problems (Owens et al., 2013; Sivertsen et al., 2014; Skogen et al., 2014), and it is thus important to include such factors as adjustment variables. The Pasch et al. study (2010) found depressive symptoms to be related to both sleep and alcohol/substance use, but that study did not explore this triad further by

adjusting for depression in the analyses. However, in a study of 1044 heavy-drinking college students, Johnsen and Breslau (2001) found that parts of the association between sleep problems and substance indeed were attributable to comorbid psychiatric problems. This finding was to some extent supported by the current study, in which controlling for symptoms of depression and ADHD reduced the magnitude of the ORs, but still, all associations remained significant in the fully adjusted models.

The many physiological alterations that adolescents undergo may also help explaining the close link between sleep changes and risk-taking behaviors, such as alcohol and drug use. Parallel changes in both the circadian rhythms and the brain's reward function activated through risk-raking behaviors, are likely not coincidental (Hasler et al., 2014b). Both animal (Logan et al., 2014) and human (Blomeyer et al., 2013) studies have shown that circadian gene variations are closely linked to substance use, and that relationship is likely to be bidirectional: adolescents with addiction problems more commonly display disrupted circadian rhythms, and also particular chronotypes have been shown to increase the risk for substance abuse (Logan et al., 2014). Neuromaging studies have shown that short sleep and sleep problems are related to an imbalance between affective and cognitive control systems, and this could lead to a higher risk-taking behavior and impair decision making (Telzer et al., 2013).

4.2 Clinical implications

The combination of high prevalence and comorbidity of sleep - and alcohol problems indicates that increased focus on these areas as targets for prevention and early intervention is warranted. It is estimated that 85% of adults with chronic insomnia receive no treatment for their condition (Mellinger et al., 1985), and nearly 20% of these resort to either untested remedies or alcohol in attempts to improve their sleep (Roth and Ancoli-Israel, 1999). This may lead to a vicious circle also for adolescents, in which alcohol or drug use as a mean of self-medication may further exacerbate the sleep problems and thereby potentially increasing the risk of later problems related to both sleep and alcohol and drugs use. The close association between sleep problems and problematic alcohol and drug use in the present study may indicate this. There is now ample evidence of strong and lasting effect of interventions based on cognitive-behavioral therapy for insomnia (CBT-I), and such non-pharmacological approaches may especially be

well suited if sleep problems co-exist with indications of drug and substance abuse. On a more structural level, changing school times aimed at compensating the increased circadian misalignment have been shown to have a beneficial effect of both on improved quality of life as well as academic performance (Carrell et al., 2011; Danner and Phillips, 2008; Owens et al., 2010). While few studies have been conducted in adolescents with known substance abuse, one notable exception was a six week behavioral sleep treatment program for adolescents with substance abuse, which demonstrated improvements on both the sleep and aggression outcomes, supporting the feasibility of including sleep as a treatment target (Haynes et al., 2006). However, it remains to be seen whether such intervention also may impact alcohol- and drug-related problems.

Similarly, assessment of sleep could be included in assessment and interventions for alcohol and drug use, and an even broader perspective including mental health problems could be warranted when adolescents present with these behaviors.

4.3 Methodological considerations

There are several strengths in the current study. First, this is the largest population-based study of adolescents using well-defined measures of both sleep and alcohol/drug use. Second, the data collection is recent allowing for an updated and contemporary insight into the current status of alcohol and drug use, the presence of potential alcohol and drug use problems and associations with sleep problems. Third, the current study is the first to include a broad range of detailed sleep parameters when assessing the link to substance use. Fourth, the study included different measures of alcohol and drug use, as well as the validated CRAFFT questionnaire for alcohol-related or drug-related problems. Finally, we were able to adjust for important confounding factors, including well-validated questionnaires measuring symptoms of depression and ADHD.

There are some methodological limitations of the present study that deserves mention. First, while an association between sleep and alcohol/drugs use was demonstrated, conclusions regarding the temporal sequence warrant longitudinal studies with multiple measurements. Although much of the literature has investigated whether sleep (exposure) has an effect on alcohol use (outcome), it has also been

demonstrated that the reverse directionality exist. For example, in a Canadian study of 942 students aged 17-25, greater alcohol use was found to predict subsequent larger bedtime differences between weekday and weekend, whereas no significant effect was observed for the reverse association (Tavernier and Willoughby, 2014). Similarly, a Canadian study of 187 Canadian students aged 17-20 showed that drinking alcohol predicted lower sleep quantity the following night (Galambos et al., 2011). Therefore, more prospective studies are needed to provide clearer insights into causality (i.e., do sleep problems predict alcohol/drug use, and vice versa). Second, the age range included in the present study was limited, and a wider range would enable a more thorough investigation of age-related associations between sleep and alcohol and drug use. Third, both the independent and dependent variables were self-reported, which could lead to bias in reporting. For example, while our definition of insomnia was tailored according to the newly revised diagnostic DSM-5 criteria, it was not based on a structured clinical interview or physiological measurements (actigraphy or polysomnography), which of provide the most accurate data on sleep. However, the use of both SOL and WASO to estimate exact sleep duration was a significant strength of the current study, as most population based studies on sleep rarely provide such detailed measures. Although self-reported sleep parameters, including SOL and WASO typically differ from those obtained from objective assessments (Lauderdale et al., 2008), recent studies have showed that such self-report sleep assessments can be recommended for the characterization of sleep parameters in both clinical and population-based research (Zinkhan et al., 2014). Also, the accuracy of self-reported SOL and WASO are generally better among adolescents than in older adults (Dillon et al., 2014), and a study of young adolescents in Hong Kong recently found good agreement between actigraphy measured and questionnaire reported sleep durations (Kong et al., 2011). Along the same lines, depression and ADHD were assessed by self-report instruments, the SMFQ and ASRS respectively, thus the lack of a clinical interview in confirming clinical diagnoses is a limitation. Taken together, the fact that all data are based on self-report may potentially inflate the associations between the sleep, drug/alcohol use and mental health measures. Fourth, sleep deficit was calculated by subtracting each adolescent's sleep duration from his or her subjectively perceived sleep need. Although a previous study from the same dataset (Hysing et

al., 2013) showed that the adolescents' average sleep need was close to experts' recommendations of 8.5 hours (Carskadon et al., 1980), evidence of adolescents' ability to accurately assess their own personal sleep need remains uncertain. Fifth, the assessment of illicit drugs did not indicate the type of drug tried and its frequency, thus limiting conclusions drawn according to the relation between sleep and more specific drugs or consumption patterns. Similarly, residual confounding cannot be ruled out. Sixth, the sample was relatively ethnically homogeneous, and future research is needed to establish if the reported patterns hold among other ethnic and racial groups. Finally, the attrition from the study could affect generalizability, with a response rate of about 53% and with adolescents in schools overrepresented. The problem with non-participation in survey research seems unfortunately to be on the rise (Morton et al., 2012). Official data show that in 2012, 92% of all adolescents in Norway aged 16-18 attended high school (The Directorate of Integration and Diversity (IMDi), 2012), compared to 98% in the current study. Based on previous research from the former waves of the Bergen Child Study (the same population as the current study), non-participants have also been shown to have more psychological problems than participants (Stormark et al., 2008), and it is therefore likely that the prevalence of mental health problems, as well as possible sleep problems and alcohol use, may be underestimated in the current study.

4.4 Conclusion

The high rate of sleep problems and use of alcohol and drugs, combined with the many detrimental consequences of these problems, represent a serious public health concern. Future research should both aim at disentangling the directionality of the link between sleep and substance use, including potential common pathways, as well as investigate the effect of interventions aimed at adolescents with comorbid sleep and drug/alcohol problems.

FIGURE LEGEND

Figure 1. Sleep duration (weekday) associated with problematic alcohol and drug use (CRAFFT total score).

REFERENCES

Adler, L.A., Shaw, D.M., Spencer, T.J., Newcorn, J.H., Hammerness, P., Sitt, D.J., Minerly, C., Davidow, J.V., Faraone, S.V., 2012. Preliminary examination of the reliability and concurrent validity of the attention-deficit/hyperactivity disorder self-report scale v1.1 symptom checklist to rate symptoms of attention-deficit/hyperactivity disorder in adolescents. J. Child Adolesc. Psychopharmacol. 22, 238-244.

American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders (Fifth ed.). American Psychiatric Publishing, Arlington, VA.

Blomeyer, D., Buchmann, A.F., Lascorz, J., Zimmermann, U.S., Esser, G., Desrivieres, S., Schmidt, M.H., Banaschewski, T., Schumann, G., Laucht, M., 2013. Association of PER2 genotype and stressful life events with alcohol drinking in young adults. PLoS One 8, e59136.

Carrell, S.E., Maghakian, T., West, J.E., 2011. A's from Zzzz's? The causal effect of school start time on the academic achievement of adolescents. Am. Econ. J. Econ. Policy 3, 62-81.

Carskadon, M.A., 2011. Sleep in adolescents: the perfect storm. Pediatr.Clin. North Am. 58, 637-647.

Carskadon, M.A., Harvey, K., Duke, P., Anders, T.F., Litt, I.F., Dement, W.C., 1980. Pubertal changes in daytime sleepiness. Sleep 2, 453-460.

Clark, D.B., Lynch, K.G., Donovan, J.E., Block, G.D., 2001. Health problems in adolescents with alcohol use disorders: self-report, liver injury, and physical examination findings and correlates. Alcohol. Clin. Exp. Res. 25, 1350-1359.

Danner, F., Phillips, B., 2008. Adolescent sleep, school start times, and teen motor vehicle crashes. J. Clin. Sleep Med. 4, 533-535.

Dewald, J.F., Meijer, A.M., Oort, F.J., Kerkhof, G.A., Bogels, S.M., 2010. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: a meta-analytic review. Sleep Med. Rev. 14, 179-189.

Dillon, H.R., Lichstein, K.L., Dautovich, N.D., Taylor, D.J., Riedel, B.W., Bush, A.J., 2014. Variability in self-reported normal sleep across the adult age span. J. Gerontol. B. Psychol. Sci. Soc. Sci. 70, 46-56.

Ellickson, P.L., Tucker, J.S., Klein, D.J., 2003. Ten-year prospective study of public health problems associated with early drinking. Pediatrics 111, 949-955.

Galambos, N.L., Howard, A.L., Maggs, J.L., 2011. Rise and fall of sleep quantity and quality with student experiences across the first year of university. J. Res. Adolesc. 21, 342-349.

Hasler, B.P., Martin, C.S., Wood, D.S., Rosario, B., Clark, D.B., 2014a. A longitudinal study of insomnia and other sleep complaints in adolescents with and without alcohol use disorders. Alcohol. Clin. Exp. Res. 38, 2225-2233.

Hasler, B.P., Soehner, A.M., Clark, D.B., 2014b. Circadian rhythms and risk for substance use disorders in adolescence. Curr. Opin. Psychiatry 27, 460-466.

Haynes, P.L., Bootzin, R.R., Smith, L., Cousins, J., Cameron, M., Stevens, S., 2006. Sleep and aggression in substance-abusing adolescents: results from an integrative behavioral sleep-treatment pilot program. Sleep 29, 512-520.

Hines, J.L., King, T.S., Curry, W.J., 2012. The adult ADHD self-report scale for screening for adult attention deficit-hyperactivity disorder (ADHD). J. Am. Board Family Med. 25, 847-853.

Huang, R., Ho, S.Y., Lo, W.S., Lai, H.K., Lam, T.H., 2013. Alcohol consumption and sleep problems in Hong Kong adolescents. Sleep Med. 14, 877-882.

Hysing, M., Haugland, S., Stormark, K.M., Bøe, T., Sivertsen, B., 2014. Sleep and school attendance in adolescence: results from a large population-based study. Scand. J. Public Health 43, 2-9.

Hysing, M., Pallesen, S., Stormark, K.M., Lundervold, A.J., Sivertsen, B., 2013. Sleep patterns and insomnia among adolescents: a population-based study. J. Sleep Res. 22, 549-556.

Jacobs, E.A., Joffe, A., Knight, J.R., Kulig, J., Rogers, D., Abuse, C.S., 2001. Alcohol use and abuse: a pediatric concern. Pediatrics 108, 185-189.

Johnson, E.O., Breslau, N., 2001. Sleep problems and substance use in adolescence. Drug Alcohol Depend. 64, 1-7.

Kenney, S.R., LaBrie, J.W., Hummer, J.F., Pham, A.T., 2012. Global sleep quality as a moderator of alcohol consumption and consequences in college students. Addict. Behav. 37, 507-512.

Kenney, S.R., Lac, A., Labrie, J.W., Hummer, J.F., Pham, A., 2013. Mental health, sleep quality, drinking motives, and alcohol-related consequences: a path-analytic model. J. Stud. Alcohol Drugs 74, 841-851.

Kessler, R.C., Adler, L.A., Gruber, M.J., Sarawate, C.A., Spencer, T., Van Brunt, D.L., 2007. Validity of the World Health Organization Adult ADHD Self-Report Scale (ASRS) screener in a representative sample of health plan members. Int. J. Methods Psychiatr. Res. 16, 52-65.

Knight, J.R., Sherritt, L., Harris, S.K., Gates, E.C., Chang, G., 2003. Validity of brief alcohol screening tests among adolescents: a comparison of the AUDIT, POSIT, CAGE, and CRAFFT. Alcohol. Clin. Exp. Res. 27, 67-73.

Knight, J.R., Shier, L., Bravender, T., Farrell, M., VanderBilt, J., Shaffer, H., 1999. A new brief screen for adolescent substance abuse. Arch. Pediatr. Adolesc. Med. 153, 591-596.

Kong, A.P., Wing, Y.K., Choi, K.C., Li, A.M., Ko, G.T., Ma, R.C., Tong, P.C., Ho, C.S., Chan, M.H., Ng, M.H., Lau, J., Chan, J.C., 2011. Associations of sleep duration with obesity and serum lipid profile in children and adolescents. Sleep Med. 12, 659-665.

Lauderdale, D.S., Knutson, K.L., Yan, L.L., Liu, K., Rathouz, P.J., 2008. Self-reported and measured sleep duration: how similar are they? Epidemiology 19, 838-845.

Logan, R.W., Williams, W.P., 3rd, McClung, C.A., 2014. Circadian rhythms and addiction: mechanistic insights and future directions. Behav. Neurosci. 128, 387-412.

Lundervold, A.J., Posserud, M., Stormark, K., Breivik, B., Hysing, M., 2013. Symptoms of depression as reported by Norwegian adolescents on the Short Mood and Feelings Questionnaire. Front. Psychol. 4, 613.

McKnight-Eily, L.R., Eaton, D.K., Lowry, R., Croft, J.B., Presley-Cantrell, L., Perry, G.S., 2011. Relationships between hours of sleep and health-risk behaviors in US adolescent students. Prev. Med. 53, 271-273.

Mellinger, G.D., Balter, M.B., Uhlenhuth, E.H., 1985. Insomnia and its treatment. Prevalence and correlates. Arch. Gen. Psychiatry 42, 225-232.

Morton, S.M.B., Bandara, D.K., Robinson, E.M., Carr, P.E.A., 2012. In the 21st Century, what is an acceptable response rate? Aust. N.Z. J. Public Health 36, 106-108.

O'Brien, E.M., Mindell, J.A., 2005. Sleep and risk-taking behavior in adolescents. Behav. Sleep Med. 3, 113-133.

Owens, J., Gruber, R., Brown, T., Corkum, P., Cortese, S., O'Brien, L., Stein, M., Weiss, M., 2013. Future research directions in sleep and ADHD: report of a consensus working group. J. Atten. Disord. 17, 550-564.

Owens, J.A., Belon, K., Moss, P., 2010. Impact of delaying school start time on adolescent sleep, mood, and behavior. Arch. Pediatr. Adolesc. Med. 164, 608-614.

Pasch, K.E., Laska, M.N., Lytle, L.A., Moe, S.G., 2010. Adolescent sleep, risk behaviors, and depressive symptoms: are they linked? Am. J. Health Behav. 34, 237-248.

Pedersen, W., Skrondal, A., 1998. Alcohol consumption debut: predictors and consequences. J. Stud. Alcohol 59, 32-42.

Roebuck, M.C., French, M.T., Dennis, M.L., 2004. Adolescent marijuana use and school attendance. Econ. Educ. Rev. 23, 133-141.

Roehrs, T., Roth, T., 2001. Sleep, sleepiness, sleep disorders and alcohol use and abuse. Sleep Med. Rev. 5, 287-297.

Roenneberg, T., Kuehnle, T., Juda, M., Kantermann, T., Allebrandt, K., Gordijn, M., Merrow, M., 2007. Epidemiology of the human circadian clock. Sleep Med. Rev. 11, 429-438.

Roth, T., Ancoli-Israel, S., 1999. Daytime consequences and correlates of insomnia in the United States: results of the 1991 National Sleep Foundation Survey. II. Sleep 22 Suppl. 2, S354-358.

Sivertsen, B., Harvey, A.G., Lundervold, A.J., Hysing, M., 2014. Sleep problems and depression in adolescence: results from a large population-based study of Norwegian adolescents aged 16-18 years. Eur. Child Adolesc. Psychiatry 23, 681-689.

Skogen, J.C., Bøe, T., Knudsen, A.K., Hysing, M., 2013. Psychometric properties and concurrent validity of the CRAFFT among Norwegian adolescents. Ung@hordaland, a population-based study. Addict Behav. 38, 2500-2505.

Skogen, J.C., Harvey, S.B., Henderson, M., Stordal, E., Mykletun, A., 2009. Anxiety and depression among abstainers and low-level alcohol consumers. The Nord-Trondelag Health Study. Addiction 104, 1519-1529.

Skogen, J.C., Overland, S., Knudsen, A.K., Mykletun, A., 2011. Concurrent validity of the CAGE questionnaire. The Nord-Trondelag Health Study. Addict. Behav. 36, 302-307.

Skogen, J.C., Sivertsen, B., Lundervold, A.J., Stormark, K.M., Jakobsen, R., Hysing, M., 2014. Alcohol and drug use among adolescents: and the co-occurrence of mental health problems. Ung@hordaland, a population-based study. BMJ Open 4, e005357.

Stormark, K.M., Heiervang, E., Heimann, M., Lundervold, A., Gillberg, C., 2008. Predicting nonresponse bias from teacher ratings of mental health problems in primary school children. J. Abnorm. Child Psychol. 36, 411-419.

Tavernier, R., Willoughby, T., 2014. A longitudinal examination of the bidirectional association between sleep problems and social ties at university: the mediating role of emotion regulation. J. Youth Adolesc. 44, 317-330.

Telzer, E.H., Fuligni, A.J., Lieberman, M.D., Galvan, A., 2013. The effects of poor quality sleep on brain function and risk taking in adolescence. NeuroImage 71, 275-283.

Thapar, A., McGuffin, P., 1998. Validity of the shortened Mood and Feelings Questionnaire in a community sample of children and adolescents: a preliminary research note. Psychiatry Res. 81, 259-268.

The Directorate of Integration and Diversity (IMDi), 2012. [Education participation in high schools], http://www.imdi.no/no/Fakta-og-statistikk/Fakta-og-statistikk/Utdanning/?tab=chr.

Townsend, L., Flisher, A.J., King, G., 2007. A systematic review of the relationship between high school dropout and substance use. Clin. Child Fam. Psychol. 10, 295-317.

Zinkhan, M., Berger, K., Hense, S., Nagel, M., Obst, A., Koch, B., Penzel, T., Fietze, I., Ahrens, W., Young, P., Happe, S., Kantelhardt, J.W., Kluttig, A., Schmidt-Pokrzywniak, A., Pillmann, F., Stang, A., 2014. Agreement of different methods for assessing sleep characteristics: a comparison of two actigraphs, wrist and hip placement, and self-report with polysomnography. Sleep Med. 15, 1107-1114.

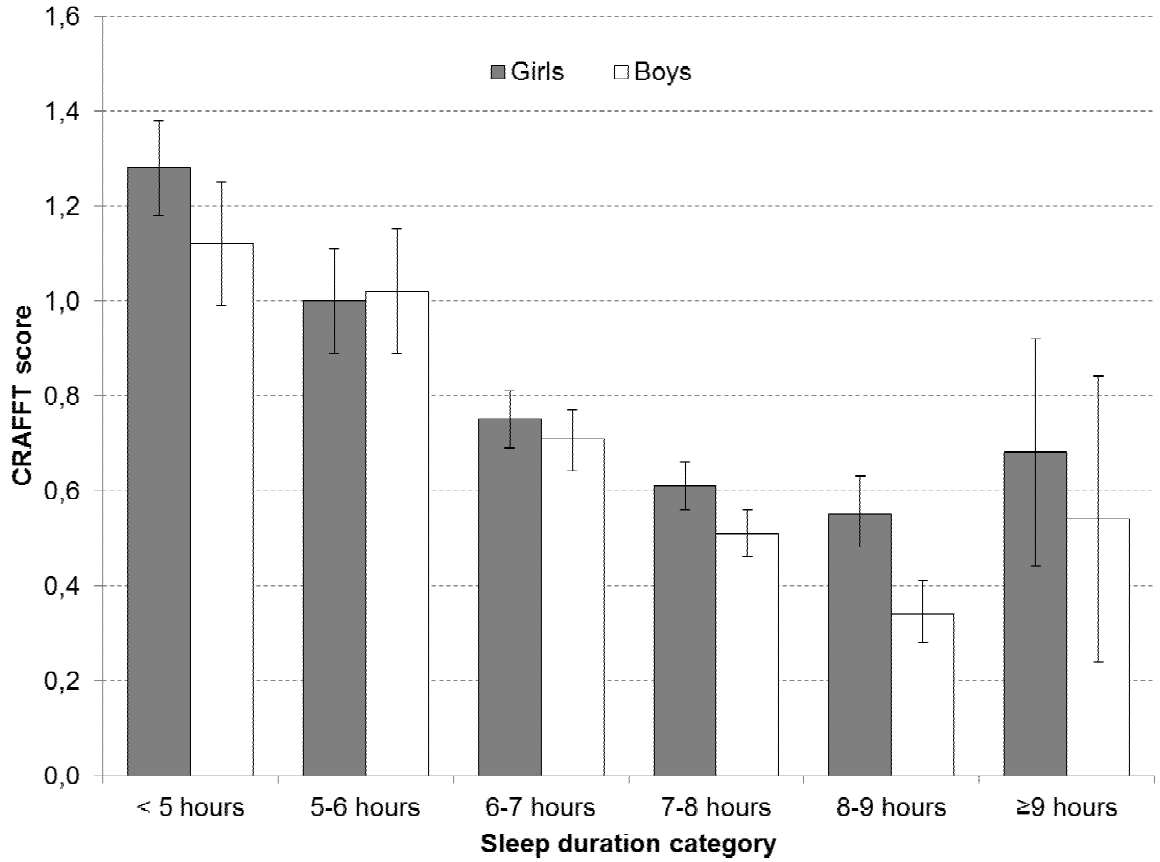


Figure 1.

AUTHOR DISCLOSURES

Role of Funding Source: Nothing declared

Contributors: Author BS and MH were involved in acquisition of data. Authors BS, JS and MH were responsible for conception and design of the study, conducted the statistical analysis and drafted the manuscript. Authors RJ gave critical revision of the manuscript for important intellectual content. Authors BS, JS MH had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

Conflict of Interest: No conflict declared:

Table 1. Demographical and clinical variables in the youth@hordaland study. N= 9,846

	% / mean	n / S.D.
Demographical variables		
Age (mean, SD)	17.9	0.8
Girls	53.3%	5252
Maternal education (% yes, n)		
Primary school	10.1%	742
Secondary school	41.3%	3042
College/university	48.6%	3581
Paternal education (% yes, n)		
Primary school	10.6%	763
Secondary school	46.4%	3343
College/university	43.1%	3106
Alcohol variables		
Ever consumed alcohol (% yes, n)	76.4%	6914
Ever tried illicit drugs (% yes, n)	9.9%	927
Intoxication (> 10 times)	27.1%	1831
Problematic alcohol and drug use (CRAFFT-score ≥ 2)	18.6%	1730
Sleep variables		
Sleep duration, weekday (mean, SD)	6:25	1:39
Sleep deficit, weekday (mean, SD)	2:09	2:30
Bedtime difference (weekday vs weekend) (mean, SD)	2:28	2:14
Insomnia (% yes, n)	18.5%	1763

Table 2. Sleep parameters associated with measures of alcohol use/misuse.

		Ever consumed alcohol				90th centile alcohol consumption				Intoxication > 10times			
		Model 1*		Model 2		Model 1*		Model 2		Model 1*		Model 2	
	n (%)	OR	(95% CI)	OR	(95% CI)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration (weekday)													
< 5 hrs	1415 (15.5%)	3.14	2.42-4.06	2.30	1.75-3.01	4.26	2.79-6.52	3.12	2.02-4.83	2.19	1.68-2.84	1.89	1.44-2.49
5-6 hrs	1057 (11.5%)	2.49	1.91-3.24	2.05	1.57-2.68	2.51	1.59-3.95	2.10	1.32-3.33	1.63	1.23-2.15	1.47	1.11-1.96
6-7 hrs	2466 (26.9%)	1.85	1.51-2.26	1.64	1.34-2.02	2.12	1.39-3.22	1.93	1.26-2.95	1.30	1.02-1.67	1.23	0.96-1.58
7-8 hrs	2949 (32.2%)	1.37	1.13-11.65	1.32	1.09-1.61	1.69	1.09-2.55	1.65	1.08-2.52	0.97	0.76-1.24	0.95	0.74-1.22
8-9 hrs	1113 (12.2%)	1.00		1.00		1.00		1.00		1.00		1.00	
≥ 9 hrs	152 (1.7%)	0.91	0.56-1.47	0.88	0.54-1.43	4.58	2.26-9.27	4.25	2.09-8.66	1.61	0.91-2.84	1.56	0.88-2.77
Sleep deficit (weekday)													
>4 hrs	1482 (19.2)	1.77	1.45-2.16	1.34	1.08-1.65	2.87	2.25-3.66	2.30	1.77-2.98	2.29	1.89-2.78	2.07	1.68-2.54
3-4 hrs	861 (11.1%)	1.66	1.31-2.11	1.42	1.11-1.81	1.39	1.00-1.93	1.26	0.90-1.76	1.59	1.26-2.01	1.52	1.20-1.92
2-3 hrs	1279 (16.5%)	1.24	1.03-1.49	1.09	0.90-1.32	1.23	0.92-1.65	1.16	0.86-1.56	1.39	1.13-1.69	1.33	1.09-1.63
< 2 hr	4109 (53.1%)	1.00		1.00		1.00		1.00		1.00		1.00	
Bedtime difference (weekday vs weekend)													
>4 hrs	737 (7.8%)	2.78	2.08-3.71	2.47	1.85-3.33	4.14	3.04-5.65	3.69	2.69-5.07	3.17	2.57-3.90	2.99	2.42-3.69
3-4 hrs	1283 (13.5%)	2.85	2.28-3.57	2.69	2.14-3.37	3.14	2.39-4.12	3.12	2.37-4.12	2.63	2.21-3.12	2.58	2.17-3.07
2-3 hrs	3834 (40.4%)	2.15	1.87-2.47	2.10	1.82-2.42	1.61	1.27-2.03	1.61	2.67-2.04	1.76	1.53-2.02	1.75	1.53-2.01
< 2 hr	3627 (38.3%)	1.00		1.00									
Insomnia	1763 (18.5%)	1.85	1.54-2.22	1.34	1.10-1.64	1.56	1.27-1.91	1.10	0.88-1.39	1.60	1.41-1.83	1.41	1.22-1.63

* Model 1: Adjusted for age and sex; Model 2: Additional adjustment for parental education, and symptoms of ADHD (ASRS inattention and impulsivity) and depression (SMFQ total score).

Table 3. Sleep parameters associated alcohol and illicit drug problems.

	Ever tried illicit drugs				Problematic alcohol and drug use (CRAFFT-positive (≥2)			
	Model 1*		Model 2		Model 1*		Model 2	
	OR	(95% CI)	OR	(95% CI)	OR	95% CI	OR	95% CI
Sleep duration (weekday)								
< 5 hrs	5.73	3.82-8.59	3.75	2.46-5.69	4.33	3.29-5.68	2.44	1.83-3.25
5-6 hrs	4.00	2.62-6.13	3.06	1.99-4.71	3.34	2.51-4.44	2.37	1.76-3.18
6-7 hrs	2.75	1.85-4.11	2.32	1.55-3.47	2.08	1.60-2.70	1.68	1.28-2.20
7-8 hrs	1.93	1.29-2.89	1.82	1.21-2.72	1.32	1.01-1.72	1.23	0.94-1.61
8-9 hrs	1.00		1.00		1.00		1.00	
≥ 9 hrs	2.44	1.12-5.32	2.22	1.01-4.90	1.45	0.79-2.68	1.31	0.69-2.46
Sleep deficit (weekday)								
>4 hrs	2.79	2.22-3.52	1.86	1.45-2.39	3.23	2.69-3.88	2.02	1.66-2.47
3-4 hrs	2.05	1.54-2.72	1.65	1.23-2.21	2.22	1.78-2.77	1.75	1.39-2.21
2-3 hrs	1.65	1.28-2.13	1.40	1.80-2.82	1.94	1.60-2.35	1.66	1.36-2.03
< 2 hr	1.00		1.00		1.00		1.00	
Bedtime differences (weekday vs weekend)								
>4 hrs	3.86	2.88-5.18	3.54	2.62-4.79	2.88	2.26-3.67	2.51	1.95-3.24
3-4 hrs	3.14	2.43-4.05	3.02	2.33-3.91	2.49	2.05-3.04	2.40	1.95-2.95
2-3 hrs	2.03	1.64-2.51	2.02	1.63-2.51	1.93	1.66-2.25	1.95	1.67-2.28
< 2 hr	1.00		1.00		1.00		1.00	
Insomnia (yes)	2.32	1.93-2.80	1.54	1.26-1.89	2.28	1.97-2.64	1.33	1.13-1.56

* Model 1: Adjusted for age and sex; Model 2: Additional adjustment for parental education, and symptoms of ADHD (ASRS inattention and impulsivity) and depression (SMFQ total score).